



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US99/23137 <b>(22) International Filing Date:</b> 6 October 1999 (06.10.99) <b>(30) Priority Data:</b> 09/211,444 15 December 1998 (15.12.98) US <b>(71) Applicant:</b> RAYTHEON COMPANY [US/US]; 2000 East El Segundo Boulevard, P.O. Box 902, El Segundo, CA 90245 (US). <b>(72) Inventors:</b> SOBHANI, Mohi; 3676 Sapphire Drive, Encino, CA 91436 (US). NASELOW, Arthur, B.; 10342 Northvale Road, Cheviot Hills, CA 90064 (US). DOUGHERTY, Llewellyn, S.; 8115 Delgany Avenue, Playa Del Rey, CA 90293 (US). <b>(74) Agents:</b> RAUFER, Colin; Raytheon Company, 2000 East El Segundo Boulevard, P.O. Box 902, El Segundo, CA 90245 (US) et al.		<b>(81) Designated States:</b> European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  Published <i>With international search report.</i>
<b>(54) Title:</b> PLANETARY CONNECTOR <div style="text-align: center;"> </div>		
<b>(57) Abstract</b> <p>Planetary connectors (10) for coupling signals and power between stationary and moving structures. The planetary connector comprises a pressure plate (13) that abuts a conformal pad that in turn contacts a first printed wiring board (15) having a plurality of concentric conductive rings (15a) that face the interior of the connector. A second printed wiring board (18), which may be backed by a second pressure plate, is disposed at an end of the connector distal from the first printed wiring board that has a plurality of concentric conductive rings (18a) that face the interior of the connector. A ball bearing retainer (16) that retains a plurality of metal ball bearings (17) is disposed between the flexible printed wiring boards, such that the ball bearings make electrical contact with the conductive rings of the rigid printed wiring boards. A shaft (11) extends through all components. A selected printed wiring board is mounted to a rotating structure and the other printed wiring board is mounted a stationary platform, and a plurality of bearings (12) are coupled to the shaft that allow the selected printed wiring board to rotate relative to the other printed wiring board. One embodiment of the connector comprises a flexible printed wiring board and a rigid printed wiring board. Another embodiment of the connector comprises two flexible printed wiring boards.</p>		

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## PLANETARY CONNECTOR

### BACKGROUND

The present invention relates generally to rotary connectors, and more particularly, to improved planetary connectors for use in coupling signals and power between stationary and moving structures.

5       Conventional rotary connectors employ the use of cable-wrap connectors, slip rings, roll rings, brushes and motors, and telephone wire coils. The disadvantages of conventional rotary connector designs are as follows. Cable-wrap connectors have low reliability, are expensive, are hard to install, are prone to fail in the field, and have limited rotation. Slip rings have low reliability and have an unworkable geometry. Slip  
10 rings also are prone to brush burns, and they vibrate. Roll rings are costly and have an unworkable geometry. Brush and motor designs are not applicable to the design of rotary connectors, and are expensive. Similarly, telephone wire coils are bulky, and are not generally applicable to the design of rotary connectors. Telephone cords have a relatively short life span, have limited rotation, and not readily adaptable for large  
15 number of signals.

To overcome the limitations of these conventional rotary connectors, the assignee of the present invention has developed various rotary connectors that provide a more reliable and low cost alternative to conventional rotary connectors. Such rotary connectors are disclosed in U.S. Patent No. 5,575,664, entitled "Ball Contact Rotary  
20 Connector", and U.S. Patent Application Serial No. 08/680,075, filed July 15, 1996, entitled "Spring Loaded Rotary Connector", for example, all of which are assigned to

the assignee of the present invention. The present invention is an improvement over these and other rotary connectors.

Accordingly, it is an objective of the present invention to provide for improved planetary connectors for use in coupling signals and power between stationary and  
5 moving structures.

### SUMMARY OF THE INVENTION

To accomplish the above and other objectives, the present invention provides for planetary connectors that use printed wiring technology and rolling balls. The  
10 planetary connectors are capable of coupling signals and power between stationary and moving structures.

The planetary connector comprises a pressure plate that abuts a conformal pad that in turn contacts a first printed wiring board that has a plurality of concentric conductive rings that face the interior of the connector. A second printed wiring board  
15 is disposed at an end of the connector distal from the first printed wiring board that comprises a plurality of concentric conductive rings that face the interior of the connector. A ball bearing retainer that retains a plurality of metal ball bearings is disposed between the flexible printed wiring boards, such that the ball bearings make electrical contact with the conductive rings of the rigid printed wiring boards.

20 A shaft extends through the pressure plate, rigid printed wiring boards and ball bearing retainer. A selected printed wiring board is mounted to a rotating structure and the other printed wiring board is mounted a stationary platform. and a plurality of bearings are coupled to the shaft that allow the selected printed wiring board to rotate relative to the other printed wiring board.

25 Specific advantages of the planetary connectors are that they have a low profile, have a modular construction, may be easily replaced upon failure, provide for cost saving over other technology, have relatively high reliability in harsh environments, provide for secure transmission of signals, and can rotate 360 degrees.

30 One specific purpose of the present invention is to replace bulky and unreliable slip rings that are currently used in most high performance aircraft, missiles and satellites, and naval vehicles such as submarines and surface ships. For example, the present invention may be advantageously used in satellites, night vision systems, radar systems, automobiles, helicopters, and inertial navigation systems, for example.

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### BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the present invention may be more readily understood with reference to the following detailed description taken in conjunction with the accompanying drawings, wherein like reference numerals  
5 designate like structural elements, and in which:

Fig. 1a illustrates a partial cross-sectional view of a first embodiment of a planetary connector in accordance with the principles of the present invention;

Fig. 1b illustrates a partial cross-sectional view of a second embodiment of a planetary connector in accordance with the principles of the present invention;

10 Fig. 2 illustrates a cushioned flexprint circuit used in the planetary connectors of Figs. 1a and 1b;

Fig. 3 illustrates a ball bearing retainer used in the planetary connector of Figs. 1a and 1b;

15 Fig. 4 illustrates a top view of a rigid printed wiring board and flexprint circuit used in the planetary connectors of Figs. 1a and 1b; and

Fig. 5 illustrates a bottom view of the rigid printed wiring board and flexprint circuit shown in Fig. 4.

### DETAILED DESCRIPTION

20 Referring to the drawing figures, Fig. 1a illustrates a partial cross-sectional view of a first embodiment of a planetary connector 10 in accordance with the principles of the present invention. This embodiment of the planetary connector 10 comprises a pressure plate 13 that presses against a conformal pad 14, which may be made from compressible urethane, for example. The conformal pad 14 presses against one side of  
25 a flexible printed wiring board 15, or flexprint circuit 15. The flexprint circuit 15 comprises a plurality of concentric conductive rings 15a (Fig. 3) that face the interior of the connector 10. The conductive rings 15a are coupled by way of a plurality of wires 27 to a connector 26 that is used to mate with electrical circuits external to the connector 10.

30 A rigid printed wiring board 18 is disposed at an end of the connector 10 distal from the flexprint circuit 15 and has a plurality of concentric conductive tracks 18a having grooves 18b (Fig. 4) machined therein that face the interior of the connector 10. The rigid printed wiring board 18 may be made of a brass/copper/polyimide laminate and is constructed using rigid printed wiring board technology. The conductive tracks  
35 18a are also coupled by way of a plurality of wires 27 to a connector 26 that is used to mate with electrical circuits external to the connector 10.

A ball bearing retainer 16 has a plurality of openings 16a that retain a plurality of metal ball bearings 17 therein. The grooves 18b machined in the tracks 18a constrain movement of the ball bearings 17 within a circular path. The ball bearings 17 make electrical contact with the conductive rings 15a of the flexprint circuit 15 and the  
5 conductive rings 18a of the rigid printed wiring board 18.

A rotatable shaft 11 is disposed through the pressure plate 13, the conformal pad 14, the flexprint circuit 15, the ball bearing retainer 16, and the rigid printed wiring board 18. Two bearings 12 are disposed outside of the pressure plate 13 and the rigid printed wiring board 18 which allow the shaft 11 and the rotating component(s) (i.e. the  
10 pressure plate 13, the conformal pad 14 and the flexprint circuit 15, or the rigid printed wiring board 18) to rotate.

Thus, in this first embodiment of the connector 10, the plurality of metal ball bearings 17 are sandwiched between the rigid printed wiring board 18 and the cushioned flexprint circuit 15. The rigid printed wiring board 18 may be mounted to a  
15 stationary platform and the cushioned flexprint circuit 15 may be mounted to a rotating structure or component, or vice-versa and the ball bearings 12 permit relative rotation and electrical connection therebetween. As rotation occurs the ball bearings 17 interconnect the circular conductive circuits located on the rigid printed wiring board 18 and cushioned flexprint circuit 15. Depending upon whether the rigid printed wiring  
20 board 18 or the flexprint circuit 15 is stationary or rotating, the wires 27 connected to the rotating component pass through the center of the shaft 11 and connect to the connector 26. The other stationary component has the wires 27 connected to it pass along the outside of the shaft 11 through an opening in the appropriate bearing 12 and connect to the connector 26.

25 The connector 10 thus provides for a structure wherein the ball bearings 17 are compressed between and make electrical contact with the circular conductive circuits formed on the rigid printed wiring board 18 and cushioned flexprint circuit 15. Deviations from an ideal geometry are accommodated by deformations in the flexible printed wiring board 15 (flexprint circuit 15).

30 Referring now to Fig. 1b, it illustrates a partial cross-sectional view of a second embodiment of a planetary connector 10 in accordance with the principles of the present invention. This embodiment of the planetary connector 10 is substantially the same as the planetary connector 10 of Fig. 1a, except that the rigid printed wiring board 18 is replaced by a second flexible printed wiring board 15b (flexprint circuit 15b) which is  
35 supported by a second pressure plate 13 disposed between it and a second bearing 12. In this embodiment of the planetary connector 10, the ball bearings 17 make electrical contact with the conductive rings 15a of both flexprint circuits 15, 15b.

The second embodiment of the connector 10 provides for a structure wherein the ball bearings 17 are compressed between and make electrical contact with the circular conductive circuits formed on the cushioned flexprint circuit 15 and the second flexible printed wiring board 15b (flexprint circuit 15b). Deviations from an ideal geometry are accommodated by deformations in the flexible printed wiring boards 15, 15b.

Again, in the second embodiment of the connector 10, the conductive rings 15a of the flexprint circuits 15, 15b are coupled by way of respective pluralities of wires 27 to respective connectors 26 that is used to mate with electrical circuits external to the connector 10. The wires 26 pass through the center of the shaft 11 or outside the shaft 11, depending upon which flexprint circuit 15, 15b rotates and which is stationary.

Details of the components making up the planetary connectors 10 are discussed below with reference to Figs. 2-6. Fig. 2 illustrates the cushioned flexprint circuit 15 used in the planetary connectors 10 of Figs. 1a and 1b. Typical locations of the ball bearings 17 are also shown in Fig. 2. Fig. 2 shows the plurality of concentric conductive rings 15a formed on the interior-facing surface of the cushioned flexprint circuit 15. The cushioned flexprint circuit 15 has a connector portion 21 with a plurality of connector pads 22 and a corresponding plurality of electrical traces 25 that are used to connect the conductive rings 15a to external electrical circuits (not shown). This permits coupling of signal and power to and from one side of the connector 10. It is to be understood that the manner in which electrical connections are made between the conductive rings 15a and the connector pads 22 or external electrical circuits may be accomplished using hard wiring, flexprint circuits, or any other suitable electrical connection arrangement.

Fig. 3 illustrates the ball bearing retainer 16 used in the planetary connectors 10 shown in Figs. 1a and 1b. The locations of the openings 16a through the ball bearing retainer 16 that retain the ball bearings 17 is shown. The ball bearing retainer 16 shown in Fig. 2 are disposed in the openings 16a in the ball bearing retainer 16 shown in Fig. 2.

Fig. 4 illustrates a top view of the rigid printed wiring board 18 used in the first embodiment of the connector 10 shown in Fig. 1a, and also illustrates the second flexible printed wiring board 15b used in the second embodiment of the connector 10 shown in Fig. 1b. The rigid printed wiring board 18 has a plurality of conductive grooves 18a formed on a surface that faces the interior of the connector 10. A plurality of conductive pads 24 is provided adjacent the center of the rigid printed wiring board 18 that are connected to the plurality of conductive grooves 18a. In the case of the

second flexible printed wiring board 15b, it has a plurality of conductive rings 15a or traces 15a formed on the surface that faces the interior of the connector 10.

Fig. 5 illustrates a bottom view of the rigid printed wiring board 18 and second flexible printed wiring board 15b shown in Fig. 4. In either version, a plurality of electrical connections 26 are formed between the conductive pads 24 and connectors 27 that are used to connect to the external electrical circuits. Again, it is to be understood that the manner in which the electrical connections 26 are made between the conductive pads 24 and the connectors 27 or external electrical circuits may be accomplished using hard wiring, flexprint circuits, or any other suitable electrical connection arrangement.

Thus, planetary connectors 10 have been disclosed wherein a plurality of metal ball bearings 17 are sandwiched between two flexprint circuits 15, 15b or between a printed wiring board 18 and a cushioned flexprint circuit 15. One side of the sandwich is mounted stationary on a platform and the other side is mounted via ball bearings 12 to a rotating structure or component. As rotation occurs the balls 17 interconnect circular conductive circuits 15a, 18a located on the flexprint circuits 15, 15b, or on the printed wiring board 18 and the cushioned flexprint circuit 15.

The planetary connectors 10 have a low profile, have a modular construction, may be easily replaced upon failure, provide for cost saving over other technology, have relatively high reliability in harsh environments, provide for secure transmission of signals, and can rotate 360 degrees. The planetary connectors 10 may readily replace bulky and unreliable slip rings that are used in aircraft, missiles and satellites, and naval vehicles such as submarines and surface ships. For example, the planetary connectors 10 may be used in satellites, night vision systems, radar systems, automobiles, helicopters, and inertial navigation systems, for example.

Thus, improved planetary connectors for use in coupling signal and power lines on stationary parts to rotary moving parts have been disclosed. It is to be understood that the described embodiment is merely illustrative of some of the many specific embodiments that represent applications of the principles of the present invention. Clearly, numerous and other arrangements can be readily devised by those skilled in the art without departing from the scope of the invention.



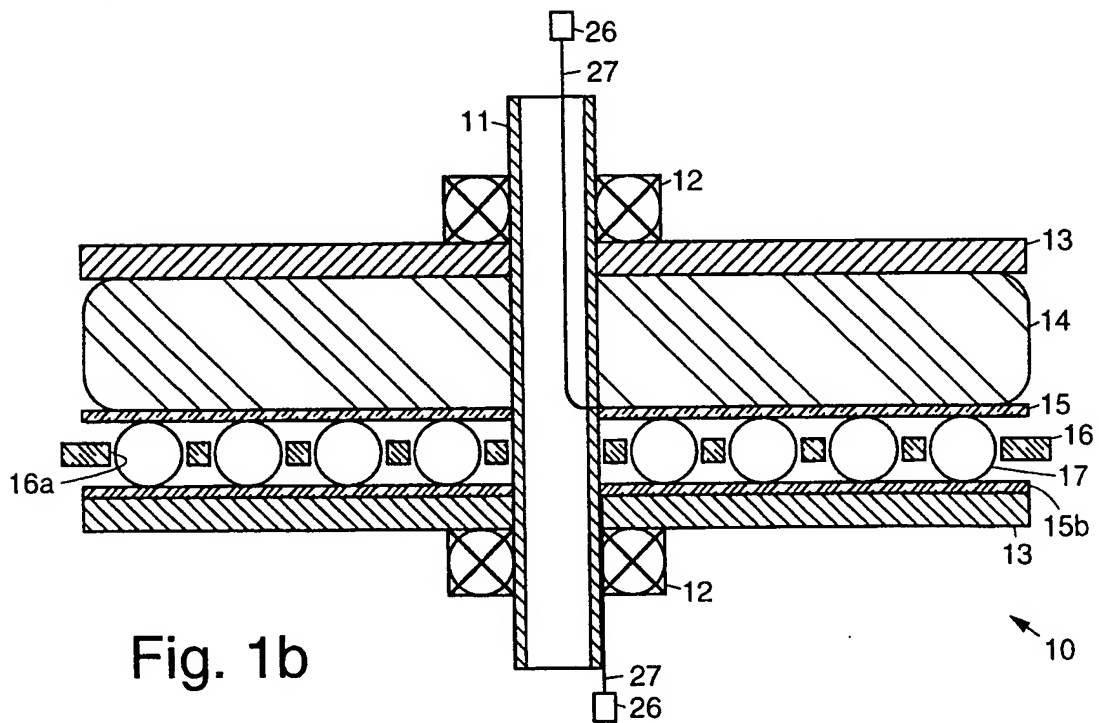
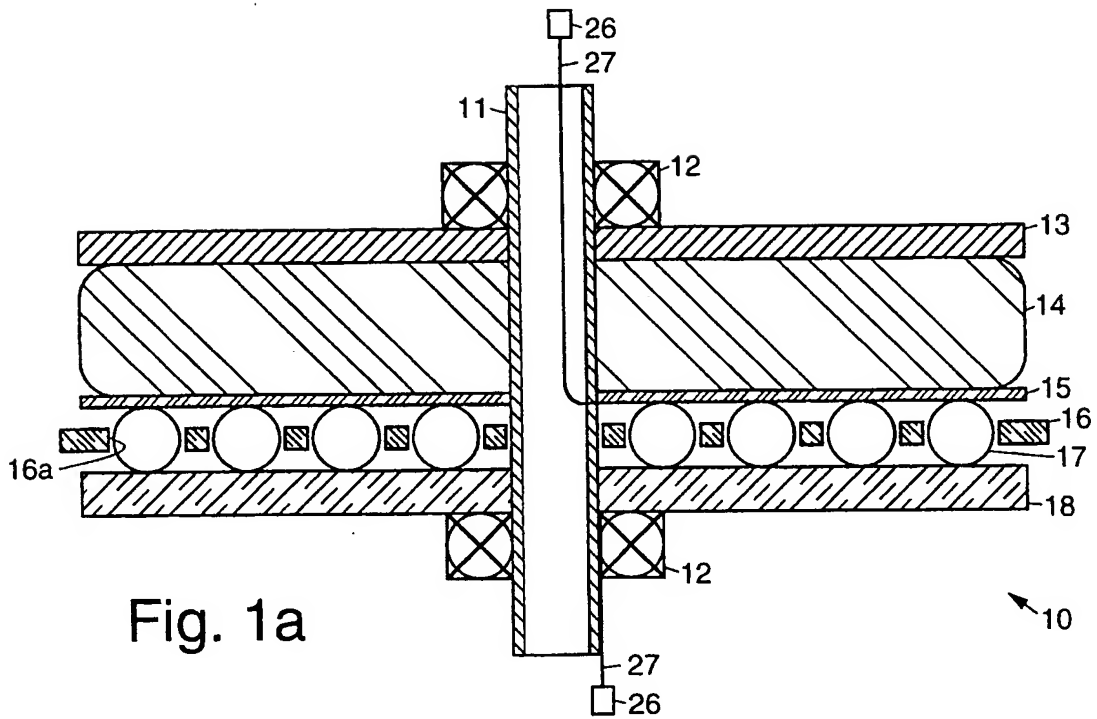
## CLAIMS

What is claimed is:

1. A planetary connector (10) characterized by:
  - a pressure plate (13);
  - a first printed wiring board (15) that comprises a plurality of concentric conductive rings (15a) that face the interior of the connector (10);
  - 5 a conformal pad (14) disposed between the pressure plate and the first printed wiring board;
  - a second printed wiring board (18) disposed at an end of the connector distal from the first printed wiring board that comprises a plurality of concentric conductive rings (18a) that face the interior of the connector;
  - 10 a ball bearing retainer (16) that retains a plurality of metal ball bearings (17) therein disposed between the flexible printed wiring boards, such that the ball bearings make electrical contact with the conductive rings of the rigid printed wiring boards;
  - a shaft (11) extending through the pressure plate, rigid printed wiring boards
  - 15 and ball bearing retainer; and
  - a plurality of bearings (12) coupled to the shaft for allowing the selected printed wiring board to rotate relative to the other printed wiring board.
2. The planetary connector (10) of Claim 1 wherein a selected printed wiring board (13, 18) is mounted to a rotating structure and the other printed wiring board (18, 13) is mounted a stationary platform.
3. The planetary connector (10) of Claim 1 wherein the second printed wiring board (18) is characterized by a plurality of concentric conductive tracks (18a) having grooves (18b) therein that face the interior of the connector.
4. The planetary connector (10) of Claim 1 wherein the second printed wiring board (18) is characterized by a rigid printed wiring board (18).

5. The planetary connector (10) of Claim 1 wherein the conformal pad (14) is characterized by compressible urethane.

6. The planetary connector (10) of Claim 1 wherein the rigid printed wiring board (18) is characterized by a brass/copper/polyimide laminate.



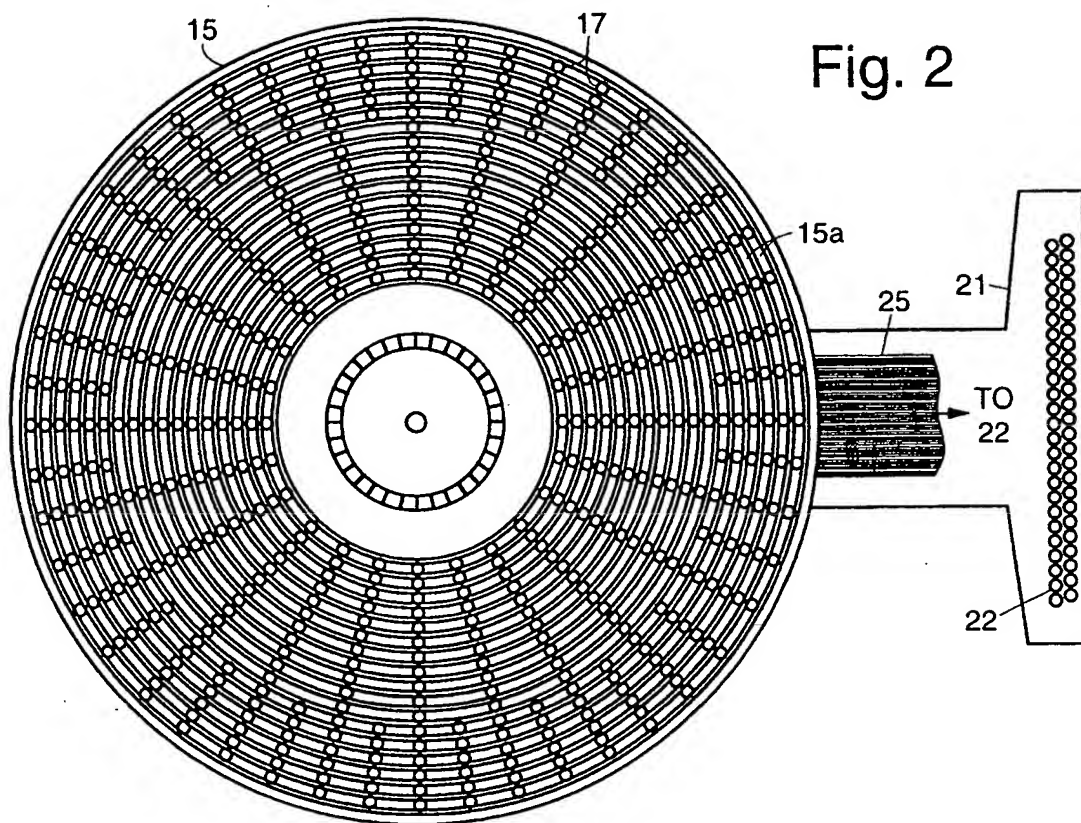


Fig. 3

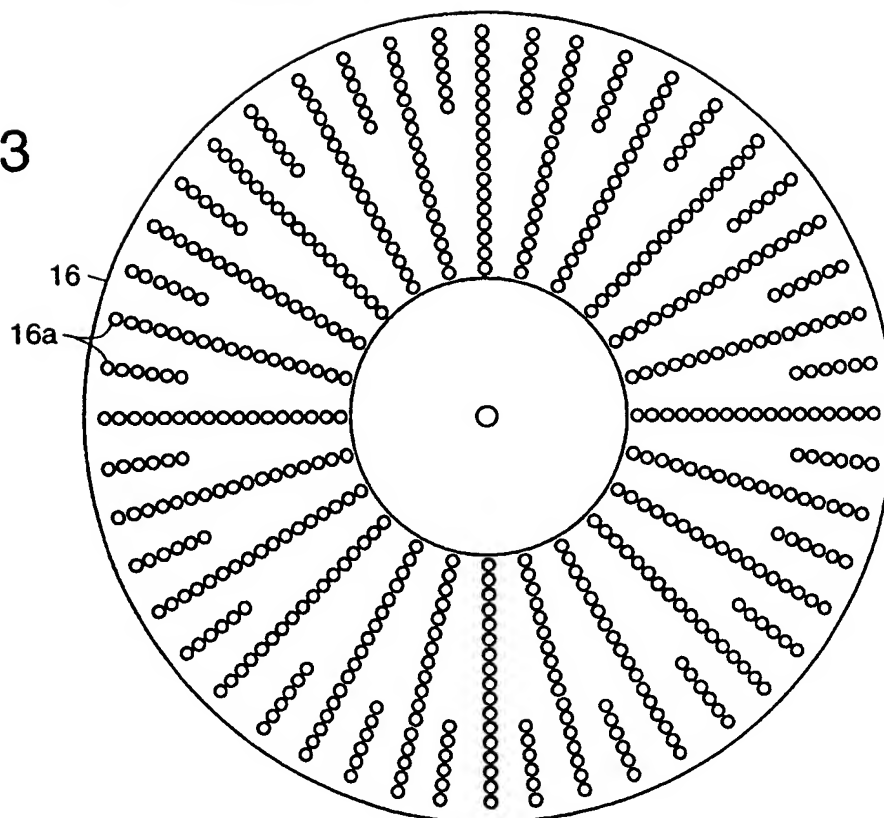


Fig. 4

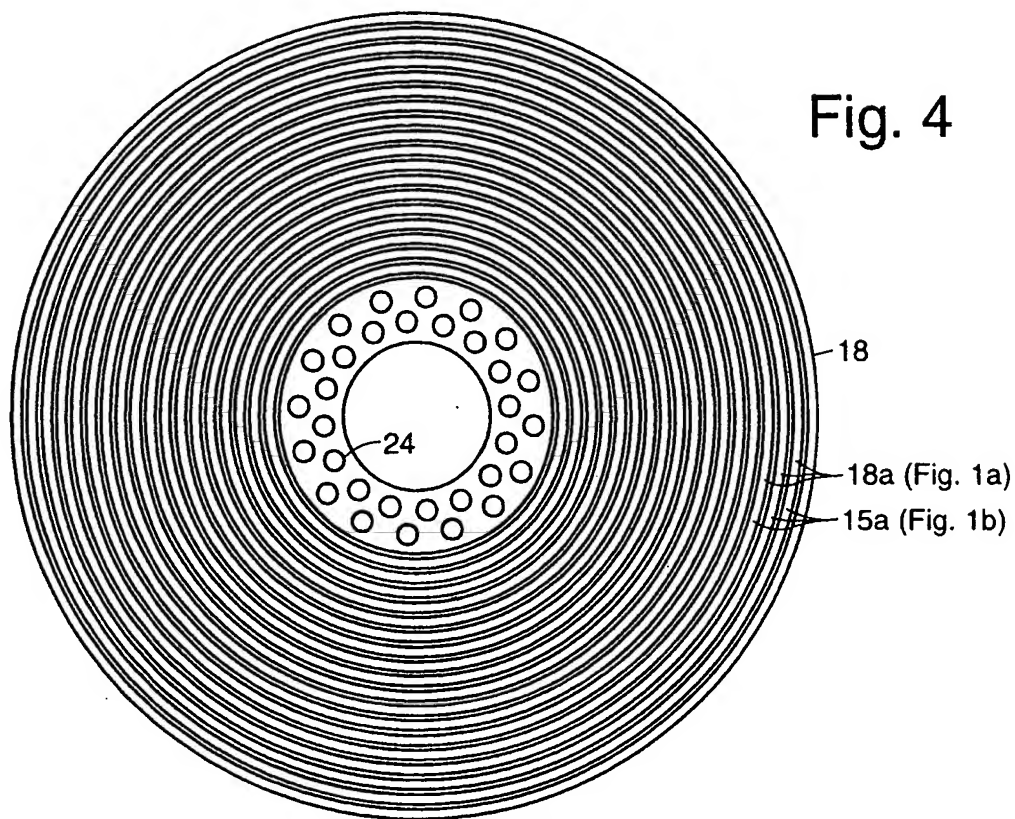
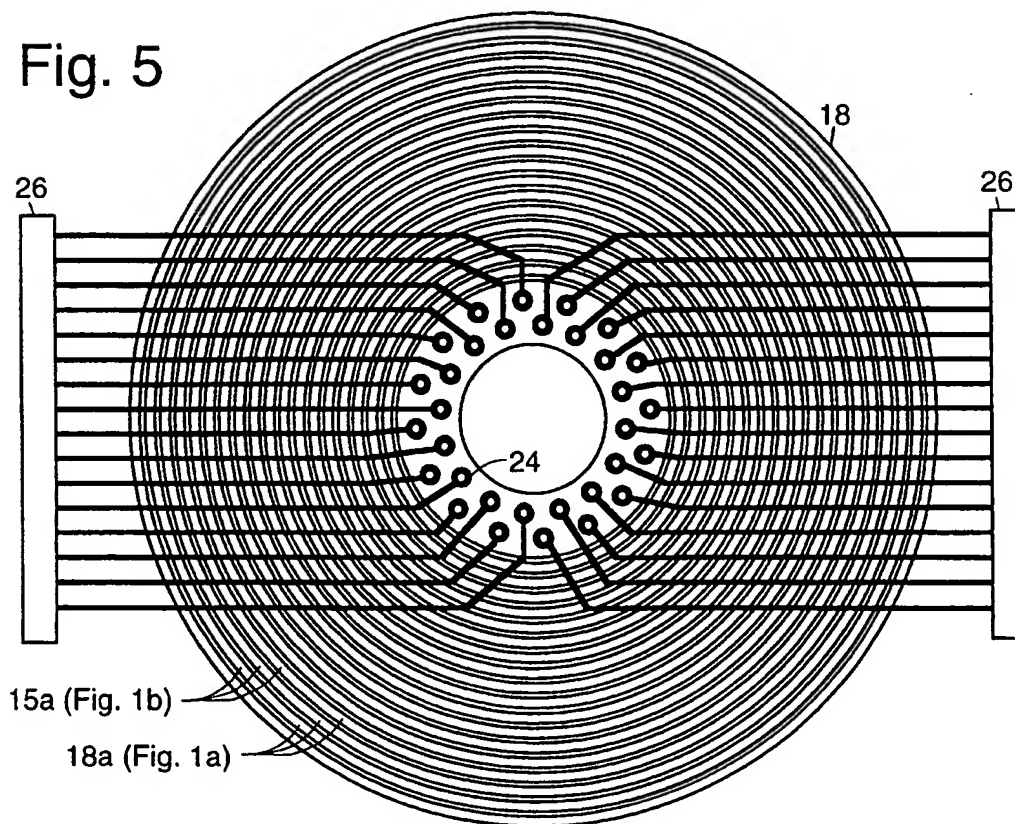


Fig. 5



# INTERNATIONAL SEARCH REPORT

Inter      national Application No  
PCT/US 99/23137

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7      H01R39/64

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7      H01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 863 587 A (HUGHES AIRCRAFT CO) 9 September 1998 (1998-09-09)	1-3
A	abstract; figures	4
A	column 2, line 27 -column 4, line 6	6
Y	US 4 647 125 A (LANDI VINCENT R ET AL) 3 March 1987 (1987-03-03)	1-3
	abstract; figure 6B	
	column 5, line 33 -column 6, line 15	
A	US 5 575 664 A (SOBHANI MOHI) 19 November 1996 (1996-11-19)	1-4
	abstract; figures 1-4	
	column 3, line 41 -column 5, line 63	
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Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 363 141 A (MOLEX INC) 11 April 1990 (1990-04-11) abstract; figure 3 column 6, line 57 -column 7, line 52 ---	1-3
A	US 5 551 882 A (WHITEMAN JR ROBERT N ET AL) 3 September 1996 (1996-09-03) abstract; figures 7,8 column 2, line 47 - line 59 -----	1

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Information on patent family members

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